is expressed in degrees per gallon, one degree being, as with the temporary hardness, the equivalent of one grain carbonate of lime per gallon.

A hard water is one that contains considerable quantities of temporary or permanent hardness per gallon; a soft water is relatively, or entirely, free from substances causing hardness. No definite line can be drawn between the two, but a water containing more than the equivalent of 7 or 8 gr. carbonate of lime per gallon would generally be accounted hard. In the preceding table the first three are soft, the others are of varying degrees of hardness.

Of the substances contributing to the permanent hardness, calcium sulphate is generally the most abundant, and the behaviour of this substance on heating requires consideration. At 93° F. it is soluble in pure water to the extent of 148 gr. per gallon, but the solubility is less at higher temperatures. At 212° F. it is about 113 gr. per gallon, while in a boiler working at 200 Ib. per square inch, where the water is at 388° F., it is soluble only to the extent of n gr. per gallon.

Boiler Scale.—When a natural water is allowed to enter a boiler under steam, without previous heating, solid matter may separate from it in the following ways:

1. By decomposition—calcium and magnesium bicarbonates being broken up and carbonate of lime and carbonate of magnesia thrown out of solution.
2. By lessened solubility—calcium sulphate in excess of 10 gr. per gallon being thrown out at high temperatures.
3. By concentration through evaporation—residual quantities of the various solids in solution being thrown out as the solution reaches the saturation point for each one.

The deposits formed in this way are of very different kinds. Where they consist almost exclusively of carbonates they are soft and even sludge-like, but where calcium sulphate is present in quantity, as is generally the case, the deposit is crystalline in character and often of rock-like hardness. The state of aggregation of such boiler scales is influenced not only by the composition but by the rate of deposition as well. In addition to the constituents

already named, they contain smaller quantities of oxide of iron, alumina, and silica, with sometimes magnesium chloride, and, in the case of sea-water, a large amount of sodium chloride. Examples of scales from a variety of sources are shown in the table on the following page.

Corrosive Waters.—As a general rule scale-forming waters are not actively corrosive, but where carbonates are present in a scale only in very small quantity, corrosion or pitting of the plates is sometimes found under-neath the crust. This appears to be due in some cases to interaction between the iron of the plate and the oxygen present in the sulphate of lime, followed by solution of the resulting oxide of iron in the saline mixture.

Waters which contain magnesium chloride even in small quantity are generally suspected of being corrosive when used in boilers, in as much as, when magnesium chloride is heated with water, a reaction occurs in which